THE USE OF THE SEGMENTED RING IN GASTRIC AND INTESTINAL ANASTOMOSES.[1]

A CLINICAL AND EXPERIMENTAL STUDY.

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In 1902 a segmented ring was described by Harrington (*Boston Medical and Surgical Journal,* November 6, 1902), the objects of which were two: (1) To furnish a mechanical aid to assist in the rapid and safe anastomosis of the intestines; (2) to make the contrivance collapsible into such small segments that their subsequent passage through the intestines would be devoid of danger or pain. The favorable reception given the ring by the profession during the past two years has encouraged us to make a report of personal cases to date, accompanied by the results of a series of animal experiments illustrating the process of repair.

Description of Ring.—The ring is made of hard aluminum in four sections. These sections are jointed firmly together by a small bar of steel, which has a shoulder and a screw-thread, and which serves as a handle. The outer surfaces of the ring are grooved to hold the ends of the intestines, which are tied in place by catgut purse-string sutures. The

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[1] Read at the meeting of the American Surgical Association, June 15, 1904.

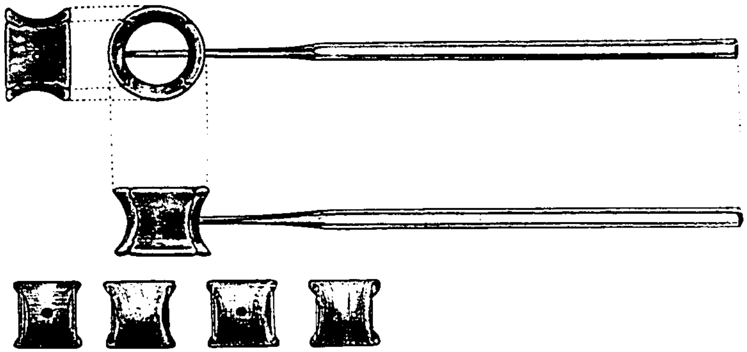

FIG. 1.—The segmented ring.

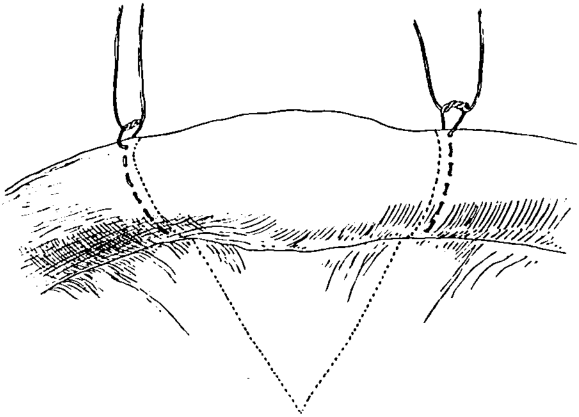

FIG. 2.—Preliminary introduction of purse-string sutures tied with one-half surgeon's knot.

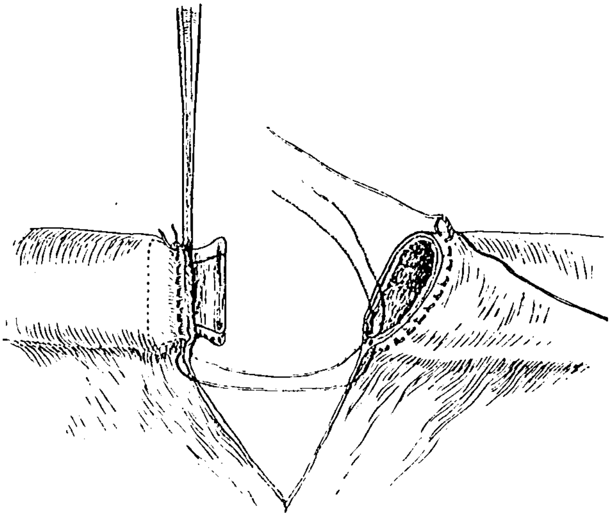

FIG. 3.—Bowel resected, ring half introduced, one gather stitch tied, mattress suture to mesenteric border.

segments fit together by means of sliding tongue-and-groove joints so rounded that they will not cut or catch in the tissues. The ring is made in three sizes. (Fig. 1.)

Diameter.	Width.	Weight of Individual Segments.
⅝ inch	½ inch	10 grains.
⅞ inch	⅝ inch	20 grains.
1⅛ inches	⅝ inch	30 grains.

The middle size is best adapted for general use; the largest may be used for sutures of the large intestine; the smallest size is best adapted for children and for cholecystenterostomy.

ANIMAL EXPERIMENTS.

Technique.—The same technique is used both for end-to-end and for lateral anastomoses; but a slight difference in details makes a separate description necessary.

End to End. Clamps are applied in the usual manner a few inches from the field of operation, and a gather stitch of No. 2 plain catgut is placed on either side of the area to be resected. This stitch circles the intestine with bites deep enough into the muscular coat to insure its not slipping, and, in order to save time later, the catgut is lightly tied with one-half of a surgeon's knot without drawing the purse-strings tight. (Fig. 2.)

The bowel is next cut away up to one-eighth of an inch from the gather stitches, because a wide margin forms a wide inturn and a correspondingly thick scar. The weak point in mechanical aids is the difficulty in obtaining a secure joint at the mesenteric border, a danger which is avoided, with the ring, by putting in a mattress stitch at this spot. This stitch includes a portion of the mesentery on each side, but is not tied at once. (Fig. 3.) The ring is now introduced, and one gather stitch tied. The mattress stitch is next tied, followed by the tying of the second gather stitch. The cut bowels now lie smoothly end to end, and, by use of the handle, can be easily moved about in convenient positions for sewing. The main stay of the suture is a Cushing's continuous stitch which penetrates the bowel into the muscularis mucosæ. This starts just to one side of the steel handle (Fig. 4) and passes around the intestine with frequent knots until it reaches the handle again from the other side. The handle is now unscrewed, leaving the ring held together by the purse-strings, and the suture continued over the hole just occupied by the handle. The cut edges of the mesentery are caught together by a few interrupted stitches. (Fig. 5.)

Lateral Intestinal and Gastro-intestinal Anastomoses. The gather stitch consists of two parallel arms crossing at one end. These arms are just wide enough apart to allow room for the incision. (Fig. 6.) The mattress stitch is omitted here, and a continuous stitch is employed to approximate the serous coats and form the anastomoses.

Hæmorrhage from the cut edges of the bowel is always controlled by tying the purse-strings, while one or two ties are usually necessary to control the bleeding from the mesentery.

It is desirable to leave the ring in place after finishing the suture, because, although having no influence upon the process of repair, it serves as a splint while the adhesions are being formed. If it causes a decided stretching of the intestines, the ring should be broken down before closing the abdomen. This is easily, and harmlessly, done by gently squeezing the circumference of the ring through the intestine. After twenty-four hours the swelling of the inverted edges of the suture is great enough of itself to hold the ring in place without the catgut purse-strings. The rings examined after one to three days were much more firmly grasped by the suture than they were at the time of the operation. The swelling of the edges of the anastomosis subsides after four to six days, leaving the gut lumen and the purse-strings stretched to a caliber considerably greater than that of the circumference of the ring. The ring accordingly collapses, although the catgut may not yet be disintegrated.

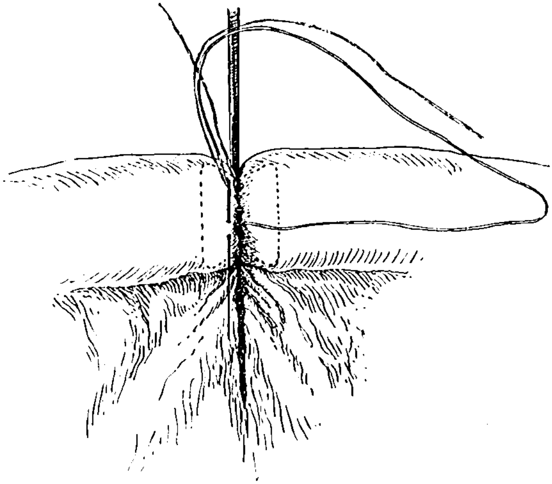

Fig. 4.—Continuous stitch beginning at one side of the handle.

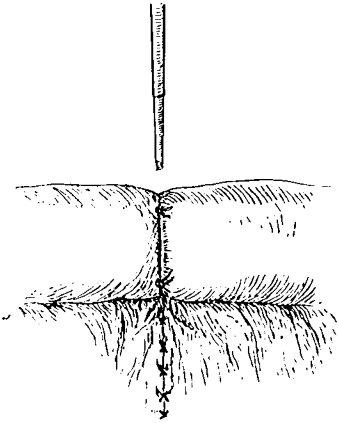

Fig. 5.—Handle unscrewed, suture completed.

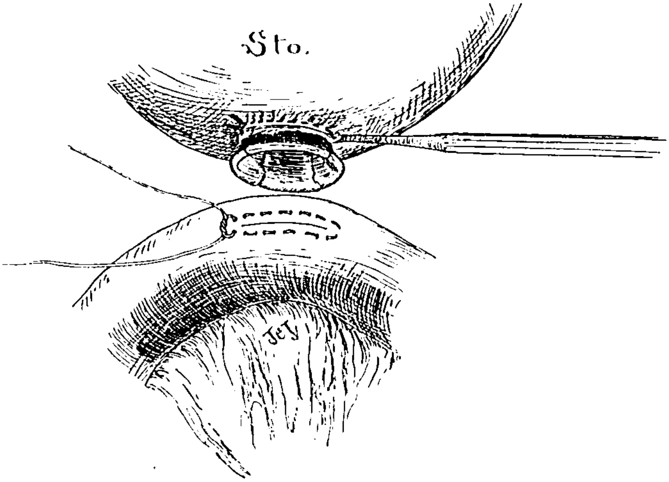

Fig. 6.—Gastro-enterostomy. Shows parallel positions of two arms of purse-string stitch. Purse-string tied on stomach side.

The passage of the segments through the intestines requires from one to three weeks. After gastro-enterostomy some or all of the segments fall back into the stomach, and, if it is patent, pass through the pylorus. That the transit through the pylorus is slow is evidenced by Experiment 17, where three of the four segments were found in the act of passing through the pylorus fourteen days after operation. After end-to-end anastomoses one or two segments pass on together, while those remaining may lie in place at the suture for several days longer.

The suture material used in these animal experiments for the continuous stitch was No. 1 Pagenstecher celloidin thread; for the mattress stitch, No. 1 chromicized catgut. No. 2 plain catgut was found most useful for the purse-string sutures. The rings used were made by Codman & Shurtleff, Boston.

Details of Animal Experiments.—A series of twenty-two experiments are reported below in which fourteen dogs and four cats were used, as follows:

End-to-end intestinal anastomoses	8
Lateral intestinal anastomoses	3
Gastro-intestinal anastomoses	7
	18
Gastrogastrostomies	4
	22

END TO END. (Dogs.)

Experiment.	Time Elapsed after Operation.	Condition of Suture at Autopsy.	Segments Found.
1	1 day	Intact	At site of suture.
2	1 day	Intact	At site of suture.
3	3 days	Slough of suture, too large ring.*	At site of suture.
4	7 days	Intact	Ileum.
5	7 days	Intact	Two in ileum. Two in rectum.
6	8 days	Intact	Ileum and rectum.
7	14 days	Intact	Not found (passed).
8	42 days	Intact	Not found (passed).

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* The intestine in this case was so stretched over the ring that it was anæmic. As it was an early case, the importance of breaking down the ring, under such circumstances, was not recognized.

Lateral Intestinal. (Dogs.)

9	5 days	Intact	Near suture.
10	10 weeks	Still alive	
11	4 weeks	Still alive	

Gastro-Enterostomies. (Dogs.)

12	3 days	Intact	Three in pylorus (stomach). One in small intestine.
13	7 days	Intact	Ileum.
14	7 days	Intact	Ileum.
15	10 days	Intact	Rectum.
16	12 days	Intact	Large intestine and rectum.
17	14 days	Intact	Three in large intestine and rectum.
18	21 days	Intact	Not found (passed).

Gastro-Gastrostomies. (Cats.)

To determine how long ring remains *in situ*.

1	24 hours	Intact	Segments held firmly in place.
2	3 days	Intact	Segments held firmly in place.
3	5 days	Intact	Segment still held in place, loosely.
4	6 days	Intact	Ring broken down. Segments *in situ*.

The Process of Repair.—The close approximation of two serous surfaces, which is characteristic of intestinal sutures, results in a rapid exudation from the apposed surfaces. This exudation appears in a very few hours and hermetically seals the wound. Every coat of the bowel is soon penetrated by this exudate, rapidly destroying the endothelium on the outside of the bowel.

Repair of the Mucous Membrane. For the first few hours after the suture the mucous membrane is the seat of a marked active hyperæmia with more or less bloody extravasation, the mucous edges being dark red and elevated from the coats below. This condition is followed by an exudation which extends into the glandular tissue until, at the end of three days, the glands disappear about the cut edge for two to five millimetres. When a large invagination has been made, in the process of suture, the submucosa becomes so swollen and œdematous that it probably interferes thereby with the circulation of the mucous membrane. Under such conditions the slough of the mucous membrane is correspondingly extensive. The amount of destruction of mucous membrane varies somewhat; but usually the slough is about three to five millimetres in width. At the end of five days, the slough generally separates, leaving a clean line. The above series of changes takes place in all sutures, although a separate suture of the mucous membrane seems distinctly to retard the repair. The reproduction of glands is more rapid in end-to-end than in lateral sutures. If the inturn has been a moderate one, the mucous membrane will cover in the ulcer in about eight days. The glands themselves, though atypical in shape, possess all the characteristics of mucous glands. At the end of eight days the line of sutures is represented by a narrow scar situated in the middle of what was formerly the ulcerated area. After gastro-enterostomy and lateral intestinal suture, the cleaning away of the slough takes place quickly; but the subsequent ingrowing of the mucous membrane is slow, since the interval to be crossed is a wide one. The process is exactly analogous to the healing of a superficial ulcer on the surface of the body. In these cases mitotic figures were seen at the end of five, but were numerous only at the end of ten, days. The nuclear division, as a rule, first came in the mucosa of the stomach. On the tenth day a single line of cells starts from the stomach and rapidly crosses the floor of the ulcer. The complete closing in of the bare area is much hindered by the presence of sutures, which, even though absorbed, leave irregular holes that are but slowly smoothed over. At the end of twenty-one days the line of suture is covered by a continuous though low mucous membrane. The line of demarcation between the stomach and intestinal glands is a sharp one, and is situated near the centre of the old ulcer. These glands, though atypically shaped, have normal functional power. (Goblet cells, etc.) (Figs. 7–13.)

The new mucous membrane has no definite muscularis mucosæ. At first it rests upon a base of dense granulation tissue. This coat is very slow to repair; but, at the end of six weeks, a substitute muscularis mucosæ has been acquired, which consists largely of connective tissue, but in which are found fibres closely resembling smooth muscle. This layer has no sharp limits, and fades away into the scar tissue beneath.

Repair of the Serous Surfaces. The formation of plastic exudate does not cease with the resulting adhesion of the inturned serous coats, but appears externally for a distance of three to five centimetres beyond the line of suture, thus acting like an external callus. The transformation of the exudate into granulation tissue is rapid. In three days a large number of new connective-tissue cells have been laid down, among which are a few new blood-vessels arising from the vessels in the underlying muscular coat. Entire organization of the inner exudate requires at least seven, the outer at least ten, days. After complete organization, the connective tissue gradually disappears, finally remaining as a thick scar, which reaches for a varying distance over the adjacent bowel and, dipping down into the depth of the suture, holds the bowel walls firmly together by thick strong bands. Fourteen days are required for the completion of this sequence.

Repair of Muscular Coats. The muscular coats play a passive rôle during the first forty-eight hours after the suture. The muscle bundles are penetrated by extravasated blood and by exudate throughout their whole thickness. After the second day new blood-vessels bud out into the exudate and assist in its organization. When the inflammatory process has subsided, the muscle ends are held together by scar tissue arising from the intermuscular connective tissue. This rapidly contracts and approximates the separated muscle ends, so that

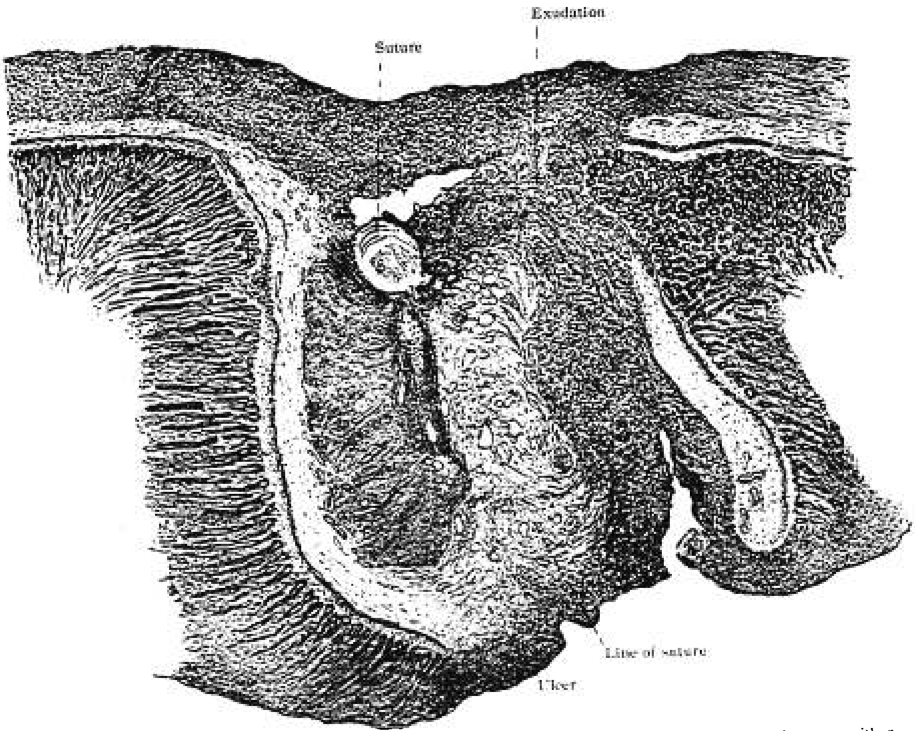

FIG. 7.—End-to-end anastomosis, three days. Note ulcer over inturned edges. Glands of mucous membrane on either side of ulcer necrotic and infiltrated.

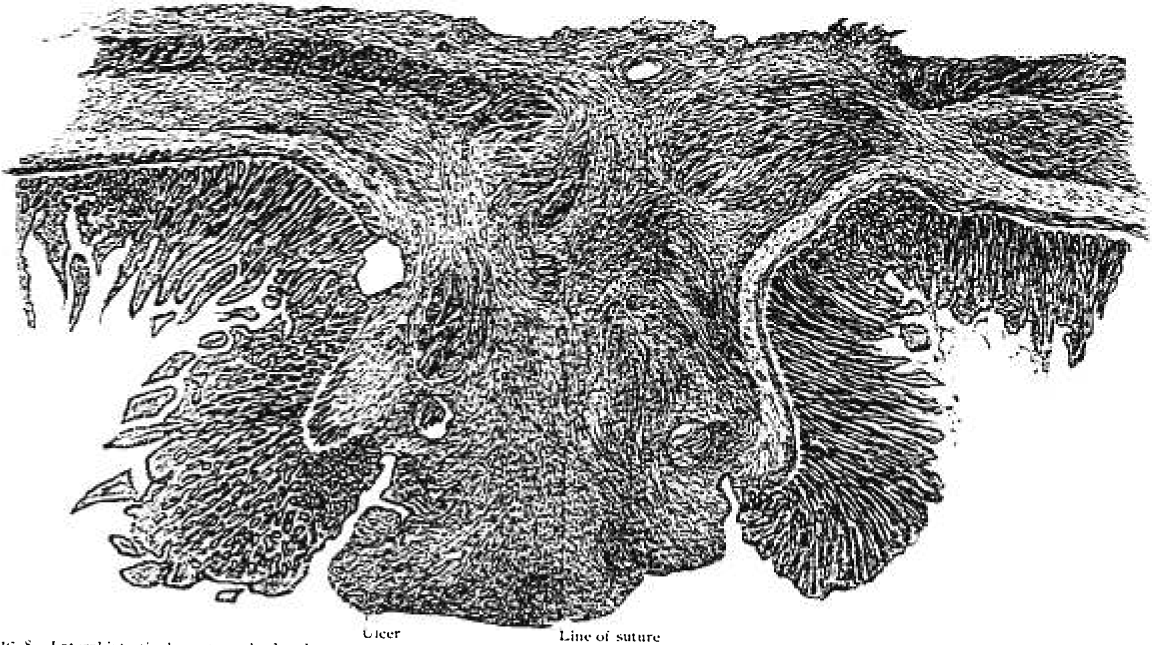

FIG. 8.—Lateral intestinal anastomosis, five days. Exudation almost entirely organized. Ulcer of denser fibrous tissue, new formation of mucous glands at margin.

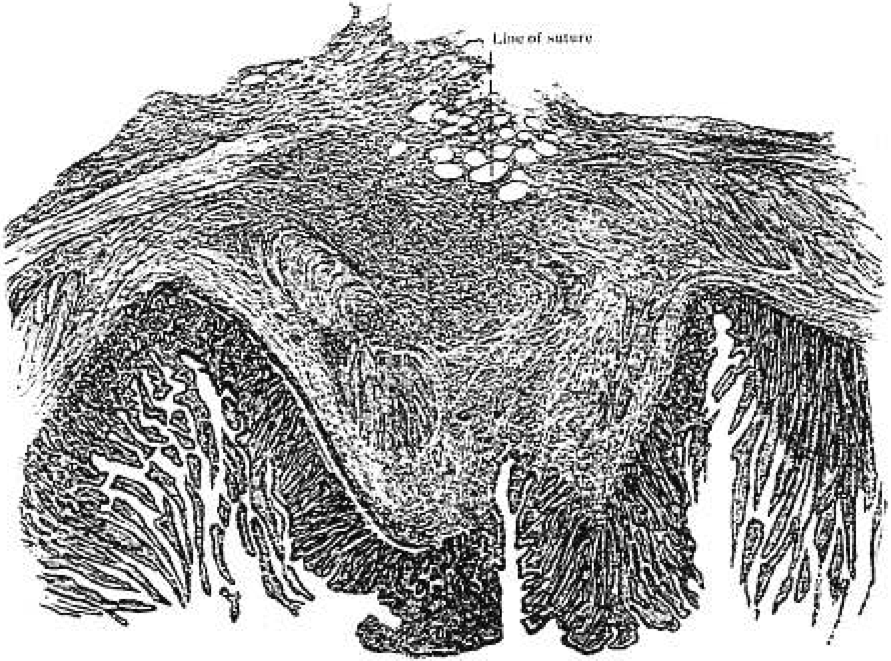

FIG. 9.—End-to-end anastomosis, eight days. Exudation entirely organized. Ulcer covered by newly formed atypical **mucous glands.**

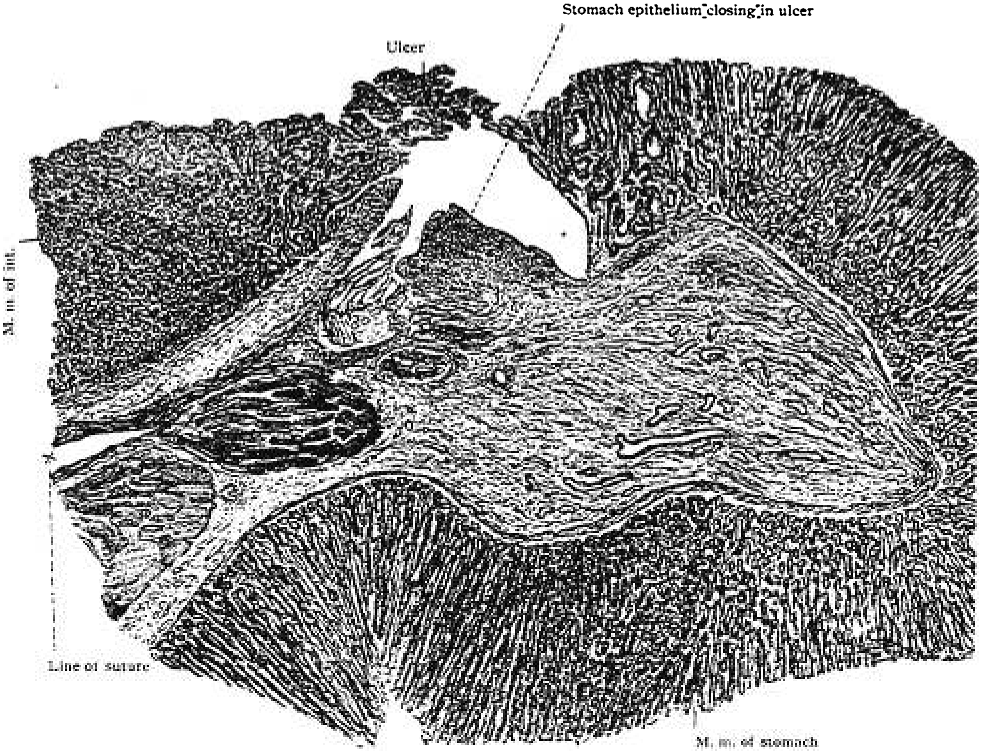

FIG. 10.—Gastro enterostomy, twelve days. Floor of ulcer formed by infiltrated granulation tissue and covered by epithelial cells arising from epithelium of the stomach. Observe that rate of growth of gastric is much more rapid than that of the intestinal epithelium.

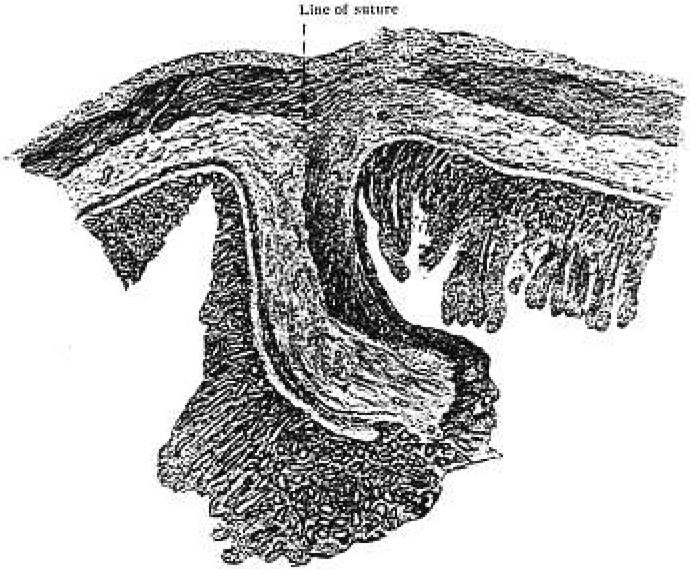

FIG. 11.—End-to-end anastomosis, fourteen days. Marked diaphragm. Granulation tissue contracted down to a dense scar. Diaphragm entirely covered by newly formed atypical glands. Marked inequality in the amount of the intestine inverted on the two sides.

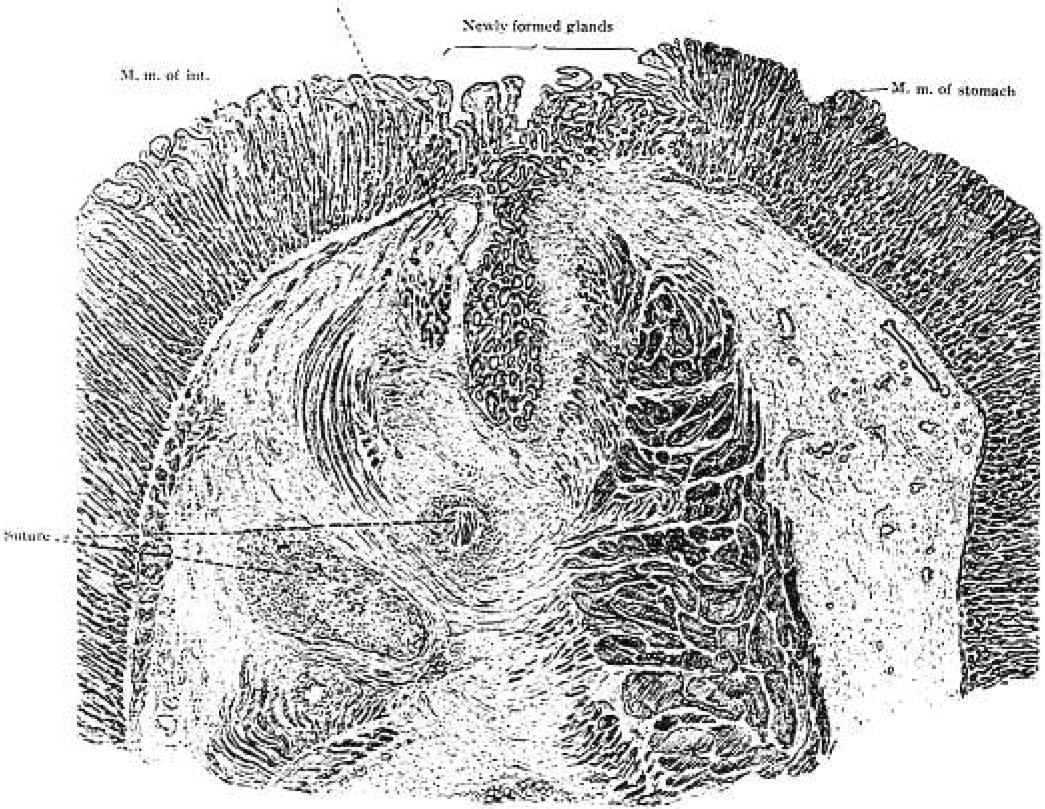

FIG. 12.—Gastro-enterostomy, twenty-one days. Suture held together by dense fibrous tissue, except at the edges, which are covered on both sides with new mucous membrane.

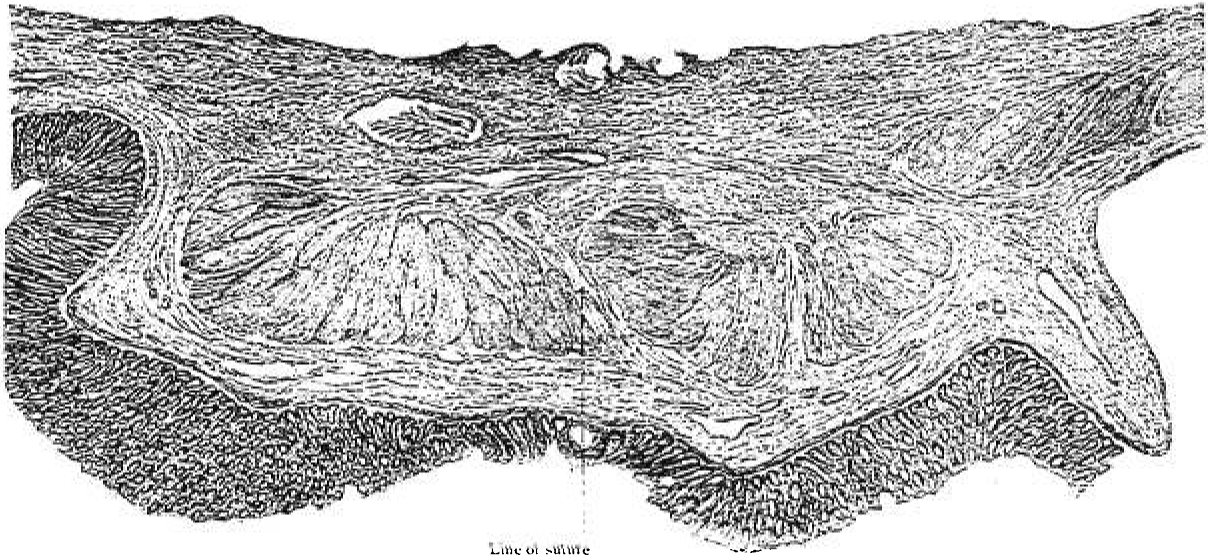

FIG. 13.—End-to-end anastomosis of large intestine, six weeks. The scar is reduced to a thin fibrous line. Inner surface entirely covered with newly formed atypical mucous membrane, thick subserous scar formation (external callus).

the ultimate scar is an extremely narrow one and may be entirely unrecognizable by the naked eye.

Repair of the Submucossa. The loose texture of the submucosa allows easy entrance to the exudate. Almost at once this layer becomes distended and œdematous for several centimetres on either side of the wound. At the end of the inturned bowel this layer is often as thick as all the others combined. As organization proceeds, the submucosa is filled with large and small blood-vessels and young connective-tissue cells, which grow parallel to the surface of the bowel out into the exudate in the bottom of the ulcer, thus forming the base of the internal ulcer. Ultimately the ulcer is converted into scar tissue and is covered by an atypical mucous membrane. From comparison with a limited number of clinically successful intestinal anastomoses in human beings, it seems that the analogy of the process in these animal experiments and in human beings is a very close one, both in histological and in gross appearances.

Advantages of the Ring.—1. Speed. A complete resection and suture can be easily done in fifteen minutes.

2. Cleanliness. Assisted by the clamps, the purse-string suture prevents even a mucous ooze while the continuous stitch is being placed.

3. An intestinal suture is more easily done over the ring than without it.

4. It is safe to use a single layer of continuous stitches, since the ring allows a perfect approximation to be made, and afterwards protects the suture until adhesions have formed.

5. The handle is very useful for holding the intestines in convenient positions for suture.

6. It is not necessary to sew up in layers, since a study of specimens from animals and human beings shows that the mucous membrane will slough in any case, and that repair is more rapid when the mucous membrane is not sutured.

7. The presence of the ring guarantees a free opening at the site of operation.

8. In case the continuous stitch should be improperly applied, the weak spots are protected by the ring itself for at least three days, until the ring breaks down. This allows strong adhesions to form.

9. After operation the ring holds the suture immovable and acts like a splint. The weights of the individual segments of the ring vary from ten to thirty grains, according to size. This is in marked contrast to most other appliances of a similar nature.

Disadvantages of the Ring.—1. General objections to mechanical contrivances.

2. General objections to one layer of sutures.

3. Too large a ring may cause sloughing of the suture from pressure.

4. A foreign body in the intestine is always a source of some danger.

REPORT OF CLINICAL CASES.

CASE I.—*Diagnosis.*—Cancer of pylorus. *Operation.*—Anterior gastro-enterostomy. *Remarks.*—Done at the Massachusetts General Hospital. Recovery after operation.

CASE II.—*Diagnosis.*—Cancer of pylorus. *Operation.*—Anterior gastro-enterostomy. *Remarks.*—Done at Massachusetts General Hospital. Death on tenth day from kink found at suture. Suture intact at autopsy.

CASE III.—*Diagnosis.*—Cancer of pylorus. *Operation.*—Posterior gastro-enterostomy. *Remarks.*—Case of Dr. G. H. Gray, of Lynn. Recovery from operation.

CASE IV.—*Diagnosis.*—Chronic pancreatitis; chronic sinuses leading into colon and stomach. *Operation.*—Posterior gastro-enterostomy. *Remarks.*—Done at Massachusetts General Hospital. Death on seventh day from cachexia, though food was taken at once by mouth and digested. Suture intact at autopsy. Three pieces of ring in ileum, one had passed out.

CASE V.—*Diagnosis.*—Gall-stone attacks and uncontrollable vomiting. *Operation.*—Posterior gastro-enterostomy. *Remarks.*

—Case of Dr. J. W. Spooner, of Hingham. Stomach found contracted to size of intestine and displaced down to umbilicus. Death in three days from uncontrollable vomiting. No autopsy permitted.

Case VI.—*Diagnosis.*—Cancer of common duct. *Operation.*—Cholecystenterostomy. *Remarks.*—Case of Dr. Philip Mooney, of Gloucester. Recovery. Lived several months.

Case VII.—*Diagnosis.*—Irreducible intussusception. *Operation.*—Lateral anastomosis. *Remarks.*—Done at Massachusetts General Hospital. Death in a few hours. Suture intact at autopsy.

Case VIII.—*Diagnosis.*—Intestinal obstruction from cancer of cæcum. *Operation.*—Lateral anastomosis. *Remarks.*—Done at Massachusetts General Hospital. Immediate feeding. Rapid recovery. In good health after several months.

Case IX.—*Diagnosis.*—Megacolon. *Operation.*—Resection, end-to-end anastomosis. *Remarks.*—Done at Massachusetts General Hospital. Immediate recovery. Later abscess about suture (three weeks). Suture intact. Abscess cavity healed by granulation. One segment passed by rectum three months after operation.

CONCLUSIONS.

1. The process of repair is as rapid after use of the segmented ring as after a plain suture.
2. The time required for the operation is, on the whole, less than that required for a straight intestinal suture.
3. Certain objections, such as weight, ulcer, difficulty of passage, etc., inherent in other mechanical contrivances, are minimized by the ring.
4. The analogy between the experimental and the human observations is so close as to show the propriety of the deductions made from the animal experiments.
5. The employment of the ring in human beings is safe and satisfactory for all sutures.

Many thanks are due to Dr. E. H. Nichols, Director of the Surgical Laboratory of the Harvard Medical School, for valuable suggestions.

The drawings which accompany this article were made by Miss Florence Byrnes.